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SLOW KAON BEAMS

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ABSTRACT

A short description is given of considerations for the design of low-momentum kaon beam lines. Relevant data for the performance of seven existing and decommissioned slow kaon beams are presented. For single-stage separated beams the observed ratio⁸ π^0/K^- is greater than 50 for momenta less than 500 MeV/c. We recommend a two-stage separated beam with perhaps an upstream "cleanup" section for maximal purity.

INTRODUCTION

K-meson factories should deliver intense pure beams of charged kaons to experiments. In this talk, I discuss requirements of low-momentum beams ($p < 500$ MeV/c). The enrichment system should purify the beams so the ratio of $\pi^0/K < 2.0$. This requirement necessitates careful source definition, judicious collimation and preferably two independent separation stages. The kaon yield should be large; this is effected by choosing an appropriate production target, maximizing the solid-angle of acceptance, and minimizing the beam length. The momentum resolution should be selectable with $0.2\% < |\Delta p/p| < 2.5\%$. Below we discuss (i) these subjects, (ii) old facilities, (iii) the impurity problem, and (iv) possible new facilities.

CONSIDERATIONS

A. Targeting

The ideal target is a short cylinder of dense material such as tungsten, platinum, or iridium. This choice minimizes depth of field problems. The central production angle can be in the range of zero to ten degrees.

B. Momentum Resolution

Momentum selection is normally performed at an intermediate, dispersed horizontal focus. Resolving power is proportional to the ratio of first-order momentum dispersion to image size and can be increased by greater bends and/or by reducing the product of source width and horizontal magnification.

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C. Yield

The yield of kaons at the final focus is given by

$$Y = \left[\int \frac{d^2N}{d\Omega dp/p} d\Omega \frac{dp}{p} \right] N_p \exp \left[- \frac{L_{\text{beam}}}{\frac{p}{Mc} \tau} \right] \quad (1)$$

where $d^2N/d\Omega dp/p$ is the number of kaons produced at the target into the desired solid angle per incident proton, N_p is the number of protons striking the target, and the exponential represents the beam fraction remaining after a length L_{beam} . The integrand in the yield equation is approximately constant over the acceptance region - the product $d\Omega dp/p$ is the solid-angle momentum acceptance of the beam line.

D. Purity

The electrostatic separator imparts angular deflections to charged particles. These result in vertical spatial separations at the mass slit. The difference in angular deflection between K and π mesons, for example, is given by¹

$$\Delta y' = \frac{LV}{gp} \left[\frac{1}{\beta_{\pi}} - \frac{1}{\beta_K} \right] \quad (2)$$

where L is the separator length, V/g is the electric field, p is the momentum, and β is the particle velocity normalized to the velocity of light. A crossed magnetic field sweeps the images vertically across the mass slit. For a given beam energy the product length times field should be maximized for best separation, preferably by the use of high fields because a short separator reduces beam loss due to kaon decay. A useful parameter is the separator rejection factor (SRF). This is the factor by which the ratio π/K is reduced when the separator is energized.

FACILITIES

Three major kaon facilities are in operation: K3 at KEK², LESB I at BNL³ and LESB II at BNL.^{4,5} Table I lists some relevant characteristics. The fluxes range from ~ 25000 - 75000 $K^-/10^{13}$ protons incident. These fluxes would be quite adequate for a kaon

factory. For 10 μ A of protons these fluxes scale up to $1.6 \times 10^6 - 4.7 \times 10^6$ K^- /pulse. Contaminations would be excessive, however, at this current.

A large number of facilities were operated in the past. Of note are beams 3 and 42 built at the ZGS,^{1,6} and the LBL 34⁷ and CERN K26⁸ beams. These were operated at momenta below 500 MeV/c. Table II lists some data for these beams. One notes the impurity is quite severe for momenta near 450 MeV/c.

THE IMPURITY PROBLEM

Bevatron and ZGS produced beams of high purity. In fact the K^- and \bar{p} beams to the bubble chambers were typically 90% pure (or better). This purity was accomplished using two stages of separation. The details are presented in Ref. 9. The authors quote a SRF of 10^5 for momenta above 1.17 GeV/c. A similar SRF would be needed for a low-momentum kaon beam (450 MeV/c) of 15-m length. In Beam 42 at the ZGS the ratio all/K^- was measured as 10^5 with the separator off.⁶

Tables I and II show that the impurity ratios are significant (>50) for single-stage separated beams at low momenta. Figure 1 shows a typical separator sweep for ZGS Beam 42. At the K^- peak the SRF values are 310 for e^- and 70 for π^- , μ^- ; the difference can be qualitatively understood because (i) e^- are produced only in the target (ii) π^- are produced in the target and surrounding region from strange particle decays; and (iii) μ^- come from π^- decays in the system. The curves are approximately asymptotic (in Fig. 1) at the K^- peak. The rejection is presumably limited by scattering of particles from vacuum chambers, windows, collimators, etc. Higher separator voltages will do little to alleviate the situation.

NEW FACILITIES

Figure 1 demonstrates that a single stage of electrostatic separation with one intermediate focus is inadequate for producing pure beams of kaons. Lobb¹⁰ and Birien⁸ have proposed single-stage beams with an upstream "cleanup section" to define the phase-space input to the separator section. I recommend use of a proven system, namely a two-stage separated beam. In this case the bulk of the contaminants are removed far upstream from the experiment. Furthermore, particles surviving the first stage because of slit scattering will most certainly be removed in the second stage of separation.

Figure 2 shows the diagrams for a short two-stage beam LBL 34, as obtained from Ref. 7. Perhaps a similar system could be coupled to a "cleanup section" as proposed above for maximal purity. The total length could be less than 16 m, and we would be ensured of meeting the desired value of $all/K^- < 2$. Kaon flux at 450 MeV/c would typically be 10^6 per pulse.

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TABLE I. Data for Existing Kaon Beams

<u>Quantity</u>	<u>Facility</u>		
	K3 (KEK)	LESB I (BNL)	LESB II (BNL)
Length (m)	14.5	15.0	15.0
Production angle (deg)	0.0	10.5	5.0
Target length (cm)	6.0	7.5	7.5
$\Delta\Omega$ (mrad)	7.3	2.6	11.0
$\Delta p/p$ (%)	± 3.0	± 2.5	± 2.5
Separator length (m)	2.0	2.1	2.1

(2 units)

Measurements for 10^{12} protons incident

K3 at 600 MeV/c	$5.2 \times 10^4 K^+$	$\pi^+/K^+ = 2.6$
LESB I at 700 MeV/c	$2.7 \times 10^4 K^-$	$\pi^-/K^- = 10.0$
LESB II at 700 MeV/c	$7.5 \times 10^4 K^-$	$\pi^-/K^- = 20.0$

TABLE II. Data for Decommissioned Kaon Beams

<u>Quantity</u>	<u>Facility</u>			
	34 LBL	3 ZGS	42 ZGS	K26 CERN
Length (m)	10.0	10.0	15.75	11.5
Production angle (deg)	0.0	0.0	0.0	0.0
Target length (cm)	7.5	5.0	7.5	3.0
Target material	Cu	Pt	Cu	Ir
$\Delta\Omega$ (mrad)	20.0	18.0	4.0	6.0
$\Delta p/p$ (%)	± 2.0	± 2.5	± 2.0	± 2.0
Separator length (m)	2.0	4.0	4.0	2.0

(2 units)

Measurements for 10^{12} protons incident

LBL 34 at 450 MeV/c	20000 K^+	$\pi^+/K^+ = 18$
ZGS 3 at 430 MeV/c	5500 K^-	$\pi^-/K^- = 160$
ZGS 42 at 430 MeV/c	430 K^-	$\pi^-/K^- = 566$
CERN K26 at 400 MeV/c	1500 K^-	$\pi^-/K^- = 50$

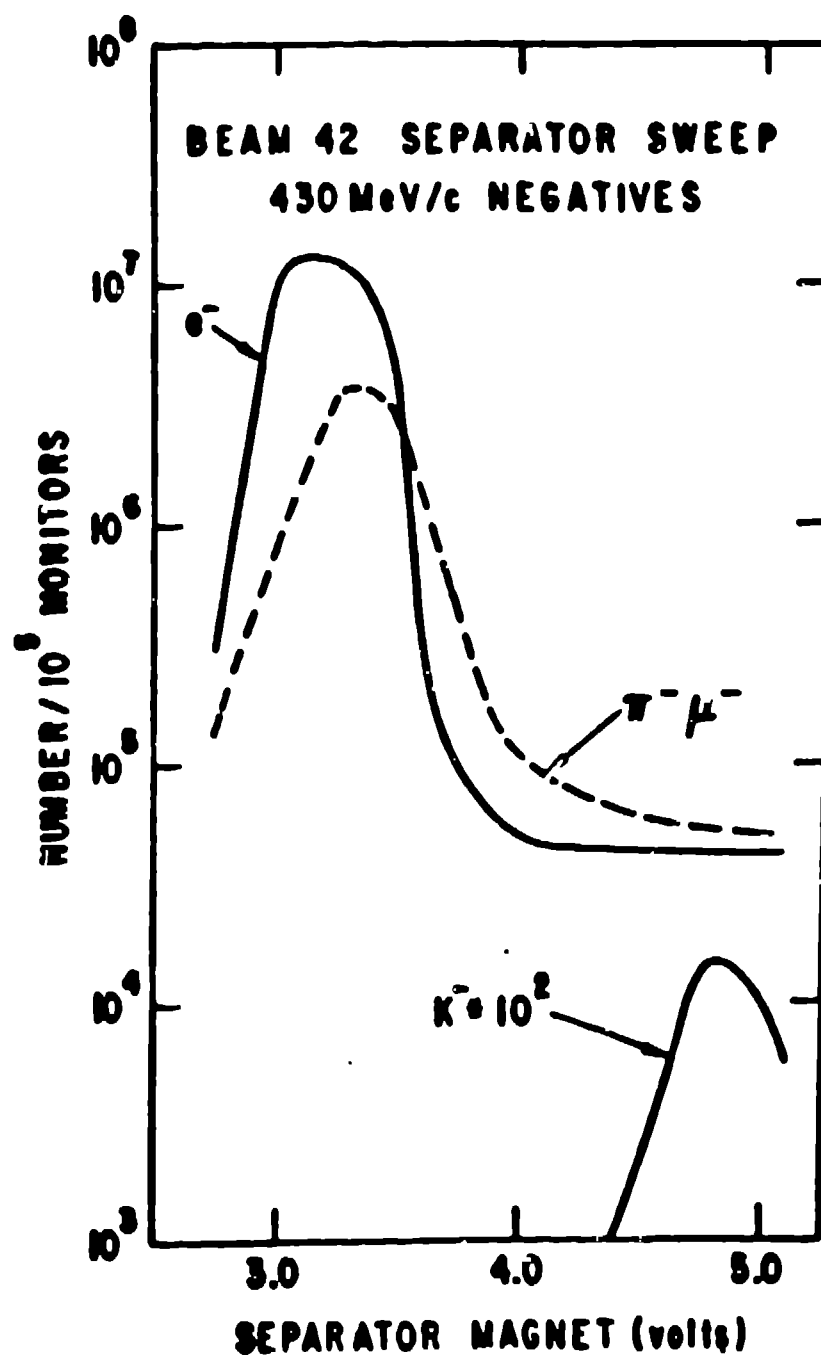


Fig. 1. Separator sweep on Beam 42 at the ZGS for 430-MeV/c negative particles. Primary beam 12.3-GeV/c protons, target 3.0-in copper, separator field 125 kV/in.

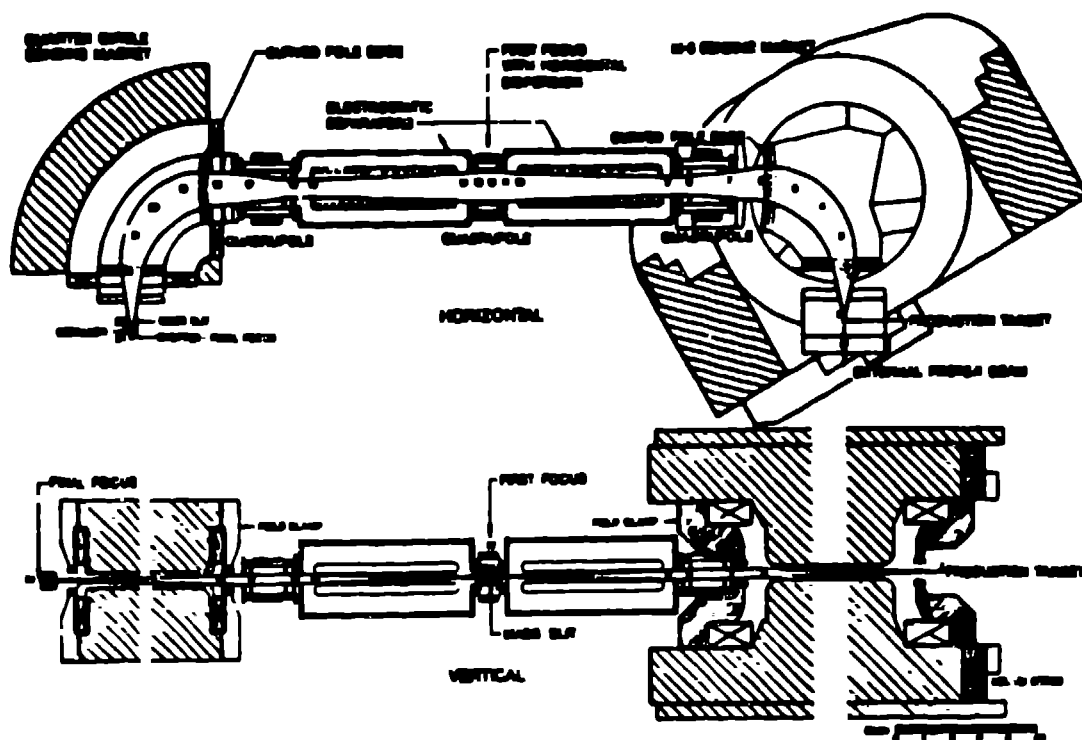


Fig. 2. Plan and elevation views of LBL Beam 34; the elements and envelopes are indicated. Copyright © 1973 by The IEEE, Inc.